EP 0031818

PCT

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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3:
E21B 43/10, 17/00, 7/20

A1

(11) International Publication Number: WO 81/00132

(43) International Publication Date: 22 January 1981 (22.01.81)

(21) International Application Number: PCT/GB80/00112

(22) International Filing Date: 2 July 1980 (02.07.80)

(31) Priority Application Number: 7923645

(32) Priority Date: 6 July 1979 (06.07.79)

(33) Priority Country: GB

(81) Designated States: AT (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent), SU, US.

Published
With international search report

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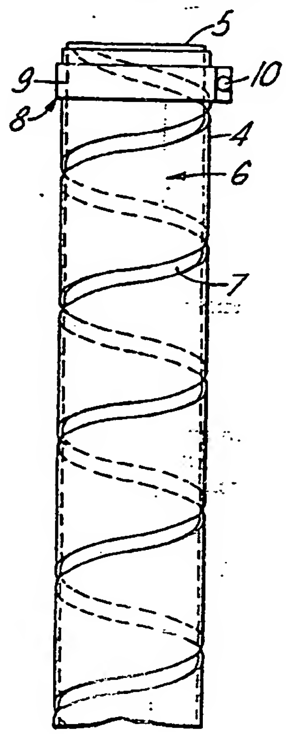
(54) Title: METHODS AND ARRANGEMENTS FOR CASING A BOREHOLE

(57) Abstract

Strip steel (4) is wound around a mandrel (5), which may be a standard length of drill pipe, to form an axially elongate resilient helix (6) in a condition of torsional stress. The stressed helix is clamped onto the mandrel with releasable clamps (8). The clamps are released when the helix is at a desired depth so that the stored energy tends to unwind the helix to increase its diameter, whereby the helix bears against the borehole wall to provide a self-supporting casing. The clamped helices may pass down through the diameter of previously cased borehole lengths and it is thus possible to form a self-supporting cased borehole of non-reducing diameter.



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METHODS AND ARRANGEMENTS FOR CASING A BOREHOLE

TECHNICAL FIELD

This invention relates to the casing of boreholes.

Boreholes are drilled for water, oil, exploratory and other purposes. A drilling mud or slurry is normally pumped down the drill pipe to carry cuttings away from the drill bit and up to the surface in the annular space between the drill pipe and the borehole wall. The hydrostatic pressure of the mud also serves to counteract pressures produced by gas or fluids released as earth formations are penetrated by the borehole. The presence of the mud and its movement can however lead to damage to the borehole or to formations through which the borehole has been drilled with possible consequent collapse of the borehole.

BACKGROUND OF THE INVENTION

It is customary in the art to protect the borehole, e.g. from such mud damage, by suspending a casing string within the borehole and introducing a cement slurry into the annular space between the string and the borehole wall to set therein. Such casings are typically formed of a string of strong, thick-walled, heavy steel pipes, each about 13 metres in length, secured together end to end as they are lowered in sequence by the drilling derrick into the borehole.

To avert the possibility of borehole damage or collapse the decision often has to be taken to insert a casing string before the borehole has attained its desired terminal

depth. Once a first length of borehole has been so cased, drilling proceeds with a drill pipe and bit lowered within the first casing string. The next decision to case a second lower length of the borehole necessarily then has to be carried out with a casing string of smaller diameter than the first length, so that it may be passed through and suspended therein. Successive casing strings must each be of smaller diameter than their predecessor, and so the borehole diameter is progressively reduced with increasing depth. There is a practical minimum casing diameter and thus a given borehole, cased in a number of stages, attains a practical maximum depth which may not be the desired terminal depth. That is particularly likely where the borehole penetrates an unexpected type of formation leading to collapse, or otherwise becomes liable to damage, and an extra, unplanned stage of casing has to be inserted.

In order to minimize the risk of not attaining the desired terminal depth it is known to commence drilling with a wide initial borehole diameter. This course has considerable disadvantages in drilling time and cost, and the very substantial expense of installing large diameter blow-out prevention and other well head equipment.. Boreholes, particularly for gas and oil, must be capped with such equipment to withstand possible high downhole pressures.

A further disadvantage of the prior art casing method is that each successive stage of casing string extends down the borehole right from the head of the borehole, and moreover each steel pipe section has to support the cumulative weight of all the sections dependent therefrom as it is lowered by the derrick. The casing sections therefore generally each have much greater tensile strength, thickness and therefore weight than is necessary for the actual task of protecting the borehole wall from damage. Particularly in offshore drilling operations, provision of a platform and a derrick of sufficient capacity to support and handle the heavy pipe sections necessary for casing a deep well, which must all be available on the platform prior to drilling,

may impose a heavy economic burden on the particular operation.

An object of the present invention is to obviate or at least mitigate some of the above described disadvantages of conventional casing techniques.

SUMMARY OF THE INVENTION

According to the present invention there is provided a method of casing a borehole comprising disposing in the borehole a strip of material in the form of an axially elongate helix, and causing the diameter of the disposed helix to increase.

The invention also provides a method of casing a borehole with steel casing material comprising winding strip steel material around a mandrel to form an axially elongate resilient helix in a condition of torsional stress, releasably securing said stressed helix around said mandrel with securing means, disposing said secured stressed helix and mandrel at a desired depth in a borehole, releasing said securing means so that the stored energy of said torsional stress tends to unwind the helix with a consequent reduction in its axial length and an increase in its diameter whereby the helix bears against the wall of the borehole to provide a self-supporting casing therefor, and withdrawing the mandrel.

In another aspect the invention provides a borehole having a self-supporting casing comprising a strip of material in the form of an axially elongate helix bearing against the wall of the borehole under the influence of stored torsional stress energy in the material of the helix.

In a further aspect the invention provides an arrangement for use in casing a borehole comprising a strip of material wound around a mandrel to form a helix in a condition of torsional stress, and securing means releasably securing said stressed helix around said mandrel.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described,

by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows schematically a section through a borehole having a conventional casing system therein;

Figure 2 shows an elevation of a portion of an arrangement for casing a borehole in accordance with the invention;

Figure 3 shows an elevation of a portion of another arrangement for casing a borehole in accordance with the invention; and

Figures 4A and 4B show diagrammatically a casing according to the invention respectively before and after torsional stressing and clamping.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to the drawings, Figure 1 shows a borehole 1 having a conventional casing system 2 comprising four strings 2a, 2b, 2c and 2d. The borehole is first drilled at a wide diameter until the first decision to case is taken. Casing 2a, e.g. 150 metres of 47 centimetre diameter pipe, is inserted in the borehole and cement slurry 3 forced down the drill pipe thereby displacing drilling mud up the annulus between the casing and the borehole wall. The cement is in turn forced by further drilling mud into the annulus where it is allowed to set to seal the annulus and support the casing.

Drilling is then resumed down through casing string 2a until the next decision to case is taken. Casing string 2b is then inserted and cemented in position. This procedure continues with successive concentric casing strings 2c and 2d. If drilling proceeds according to plan, string 2b may typically be 900 metres of 35 centimetre diameter pipe, casing 2c may typically be 2,100 metres of 25 centimetre diameter pipe, and casing 2d may typically be 4,500 metres of 18 centimetre diameter pipe to attain the desired terminal depth of 4,500 metres. However, drilling down through earth formations is beset with many uncertainties and it may prove necessary to take any one or more of the casing decisions much earlier than planned, leading to the likelihood of

the borehole not being able in practice to reach the desired terminal depth. When this occurs, the borehole may have to be abandoned and although it is highly desirable to recover the strings 2a-2d, this is not always practicable. This and the other consequent and related disadvantages of prior art casing techniques have been described above.

Figure 2 shows an arrangement for casing a borehole by a method according to the present invention. Thin flat strip steel 4, or other suitable material, is wound around a mandrel 5 to form an axially elongate substantially constant diameter helix 6. Adjacent turns of the helix preferably substantially abut one another or leave a small helical gap 7. The mandrel 5 may be a thin-walled light gauge aluminium tube for example. The strip 4 may be spring steel so that the helix is in a condition of torsional stress. Alternatively a non-spring strip steel may be employed to wind a substantially unstressed first helix of a natural diameter, e.g. on a first mandrel of larger diameter, the first helix is then subject to heat treatment resiliently to set the helix at that preferred natural diameter, and the treated first helix then coiled up on the mandrel 5 to provide the helix 6 in the desired condition of torsional stress below its natural diameter.

The stressed helix 6 is secured onto the mandrel 5 by means of releasable securing means for example in the form of circumferential clamps 8 or shear bolts to the mandrel. A clamp 8 may take the form of a steel band 9 with ends bolted together by an explosive bolt 10. One clamp 8 is provided at each end of the stressed helix and one or more other clamps 8 may be provided between the ends.

Figure 4A shows diagrammatically the strip 4 in a helix resiliently set to a natural diameter, and Figure 4B shows the same helix in its condition of torsional stress and clamped onto the mandrel 5 by means of clamps 8. Typically, the outside diameter of the stressed helix 6 is 20 centimetres, the natural diameter being about 30 centimetres, and the natural length being correspondingly shorter than

the stressed length in substantially the same ratio.

It will be appreciated that if the clamps 8 are released, the stored energy of the torsional stress tends to unwind the helix with a consequent reduction in its axial length and an increase in its diameter. In the case of the resiliently set helix, the unclamped helix will revert to the Figure 4A condition from the Figure 4B condition in the absence of any other surrounding constraint.

In practice of the present invention the clamped stressed resiliently set helix and mandrel arrangement of Figure 4B is lowered into a borehole and disposed at a desired depth. The clamps are then released by firing the explosive bolts 10, and the helix tends to unwind. When the borehole diameter at that desired position is less than the natural diameter of Figure 4A, the helix unwinds until its turns bear against the walls of the borehole to provide a self-supporting casing therefor. The mandrels 5 may then be freely withdrawn from the borehole. It will be appreciated that the force exerted by the helix 6 against the borehole wall is a function of the remaining stored spring energy, which in turn depends on the original spring characteristics and on the ratio of the borehole diameter to the natural helix diameter of Figure 4A. It is found in practice that the expanded diameter helix can provide a self-supporting and surprisingly rigid borehole casing.

Where the strip 4 is a strip of spring material wound from a coil onto the mandrel so as to store torsional energy, the arrangement of the stressed helix clamped to the mandrel is similarly disposed at the desired depth in the borehole. The securing means are released and the helix tends to unwind until its turns bear against the walls of the borehole to provide a self-supporting casing.

The outside diameter of the clamped helix of Figure 4B, including the clamps, is in practice chosen to be substantially less than the outside diameter of the released helix when in position in a borehole at a particular depth, the minimum borehole diameter at that depth being known

from the drill bit diameter used at that depth. Consequently the clamped helix arrangement of Figure 4B may be passed axially through the expanded diameter of a previously positioned helix. Thus the technical problem described in relation to Figure 1 is avoided. Successive casing lengths according to the invention may be of the same installed diameter as previously positioned casing lengths higher up in the borehole, and the borehole can therefore attain its planned terminal depth. Moreover the borehole may be of substantially constant diameter over its entire depth, avoiding the necessity for commencing drilling at a large diameter and with consequent significant reduction in total volume of hole to be drilled and weight of casing to be set for a given well objective.

The arrangements and methods according to the invention also provide considerable flexibility in the manner in which they are used, unlike the strict succession of procedural operations imposed by the conventional casing technique. A number of operational embodiments will now be described.

The clamped stressed helices may be manufactured in standard, e.g. 13 metre, length and transported to a drilling site, the mandrels being returned for re-use after placement of the helix in a borehole. Alternatively the drilling pipe sections themselves may be employed as the mandrels 5, a resiliently set unstressed helix being placed over a drill pipe section over its length between its end screw connectors. The helices may then be torsioned and clamped, the steps of this operation being performed in a factory or on site. In a further alternative, the helix may be formed and stressed by winding the strip material onto the mandrel at the borehole head. The mandrel may be progressively inserted into the borehole as the helix is progressively formed and secured thereon. Again, the drill pipe sections may themselves serve as the mandrel.

A series of the clamped stressed helices of Figure 4B may be lowered into a borehole in a sequence to form

a string, the growing weight being carried directly on the successive lengths of drill string where these serve as the mandrels. Where the mandrels are hollow tubing these may be threaded together and lowered into the borehole directly from the derrick. As previously explained, use of the present invention permits clamped helices, or a string thereof, to be lowered down through previously positioned such casing lengths higher up the borehole.

The clamps of each clamped helix are released when that helix is in a desired position and may be released together or in succession to control final positioning of the unwinding helix. For example, in the embodiment where helices are wound on and clamped directly to the pipe sections of a drill string, helices may be released in succession working progressively up the drill string from the bit to form a growing casing installed progressively downwards from the borehole head or other desired position in the borehole. In that case each clamped helix passes through the expanded diameters of all the previously installed helices prior to its own installation immediately below the adjacent previously installed helix. Alternatively, a string of clamped helices are suspended in the borehole and successive lengths released beginning with the uppermost and proceeding successively downwards.

It will be recalled that the helices contract in length when released in direct proportion to their expansion in diameter. This may be pre-calculated from the known borehole and drill bit characteristics. Thus if desired coarse allowance may be made for this effect by adjusting the depth of suspension of each casing element relative to previously placed casings prior to release of that element. Typically 100 metres of drill string may carry sufficient helices for casing about 60 metres of borehole with substantially a single layer of casing. The drill pipe can then be reloaded each time it is retracted to inspect or change the drill bit.

In the existing casing techniques, each tubular steel

casing length usually depends right down from the borehole head. In the present invention each expanded helix is generally self-supporting against the borehole wall. Thus it is now possible to case only selected lengths of a borehole, omitting if so desired lengths where the formation does not require casing.

Furthermore the strip material of the helix is thin as compared with the conventional steel casing pipes. It is therefore possible in the present invention to case a borehole length with two or more concentric helices expanded concentrically within one another so as wholly or partially to overlap and mutually reinforce one another. The second and subsequent concentric helices may be installed on a subsequent run or substantially simultaneously with the first helices. They may be wound in the same or opposite sense as the first helices. Where they are wound in the same sense the respective turns may be out of phase to provide a measure of sealing against fluid ingress into the borehole over that cased length. Figure 3 shows an arrangement wherein first and second strips 4, 11 are wound to form first and second helices 6, 12 on a common mandrel 5, which may be a drill pipe section. Helices 6 and 12 are wound in the same sense as one another with their respective turns out of phase so that each substantially seals the spiral gap 7 around the other.

Where an upper length of borehole has been cased according to the invention, it is desired to continue drilling at the same diameter as the first length. That is accomplished by use of an under-reamer drill bit as known in the art, or by other suitable means.

The clamps 8 have been described above as releasable by means of explosive bolts. Other remotely releasable clamps may be employed. For example the clamps may be provided with a weakness in lieu of the explosive bolt. The weakness may then be sheared e.g. by application of a high pressure hydraulic pulse down the drilling mud filling the borehole. Alternatively the stressed helix may be releasably

secured, e.g. by a shear bolt, to the mandrel itself.

Finally the present invention may be employed in cooperation with existing casing techniques where desired, particularly where there is a requirement for isolating water or gas-bearing formations when the characteristics of both methods can advantageously complement each other. For example a borehole, or a length of a borehole, may be cased according to the present invention with a number of helices which may or may not overlap one another and thereby substantially protect the borehole against collapse. A conventional casing, or production tubing, string of steel pipe sections may then be lowered down within the helically cased borehole. The helical casing thus protects the conventional casing string from direct borehole contact. This combined technique may be effected progressively down a borehole. A first upper length of borehole is drilled, cased according to this invention with released stressed helices which thus substantially protect the new borehole from collapse, and a conventional casing tube string is lowered down through said upper length carrying an external casing packer at its lower end. The packer is actuated, e.g. hyraulically, to seal the annulus between a lower end of this tube string and the borehole wall. The borehole is now both protected from collapse, and water, gas or oil zones above the packer are isolated from lower zones. A lower length of borehole is then drilled, with an under-reamer drill, and cased with released helices according to this invention. Those helices can pass down the tube string when they are clamped, but expand to a greater diameter than the tube string. The packer is then released and the first tube string progressively increased in length and lowered down through the second helically cased borehole length. The packer is again actuated to again seal the annulus between the borehole and casing. This procedure may be repeated as often as necessary to provide a borehole cased throughout its length with constant diameter conventional tubing, which would not have been possible in those

borehole conditions in the prior art. Additional external casing packers may be placed at appropriate points in the continuous conventional casing string to provide additional isolation of formations and to provide protection from blow-outs to surface between the borehole and the casing wall.

CLAIMS:

1. A method of casing a borehole (1) characterised by disposing in the borehole a strip (4) of material in the form of an axially elongate helix (6), and causing the diameter of the disposed helix to increase.

2. A method according to claim 1 characterised by, prior to said step of disposing the helix (6), stressing said strip (4) to provide said helix in a condition of torsional stress and releasably securing said stressed helix (6) around a mandrel (5) with securing means (8), and wherein said step of causing the diameter to increase is effected by releasing said securing means (8).

3. A method according to claim 2 characterised in that said steps of stressing said strip (4) and releasably securing said stressed helix (6) are effected on a discrete length of said strip material wound around said mandrel (5) prior to insertion of the secured stressed helix and said mandrel into the borehole.

4. A method according to claim 2 characterised in that said steps of stressing said strip (4) and releasably securing said stressed helix (6) are effected by winding strip material onto said mandrel (5) at the borehole head, said mandrel being progressively inserted into the borehole as the helix is progressively formed and secured thereon.

5. A method according to any one of claims 2 to 4 characterised in that said mandrel (5) comprises a length of borehole drill pipe.

6. A method as claimed in any one of claims 2 to 4 characterised by disposing in the borehole at least one second said strip (11) of material in the form of an axially elongate helix (12) extending at least partially within

said first-mentioned helix (6), and causing the diameter of the second helix (12) to increase.

7. A method according to claim 6 characterised by providing on said mandrel (5) said second strip (11) of material in the form of an axially elongate stressed second helix (12) extending concentrically within said first-mentioned helix (6), said helices being wound in the same sense as one another with their respective turns out of phase, and said stressed helices being releasably secured by said securing means (8).

8. A method according to any one of claims 2 to 4 characterised by providing a succession of said secured stressed helices (6) on a common said mandrel (5) or on a string of individual said mandrels disposed in said bore-hole, and releasing the securing means (8) associated with each said helix when that helix is substantially in a desired position in the borehole.

9. A method according to claim 8 characterised in that the securing means (8) associated with at least one said secured stressed helix (6) in said succession is released after that helix has been lowered axially through at least one said helix of expanded diameter whose securing means had previously been released.

10. A method of casing a borehole with steel casing material characterised by winding strip steel material (4) around a mandrel (5) to form an axially elongate resilient helix (6) in a condition of torsional stress, releasably securing said stressed helix around said mandrel with secur-ing means (8), disposing said secured stressed helix and mandrel at a desired depth in a borehole, releasing said securing means so that the stored energy of said torsional stress tends to unwind the helix with a consequent reduction in its axial length and an increase in its diameter whereby

the helix bears against the wall of the borehole to provide a self-supporting casing therefor, and withdrawing the mandrel.

11. A borehole (1) having a self-supporting casing comprising a strip of material (4) in the form of an axially elongate helix (6) bearing against the wall of the borehole under the influence of stored torsional stress energy in the material of the helix.

12. An arrangement for use in casing a borehole characterised by a strip of material (4) wound around a mandrel (5) to form a helix (6) in a condition of torsional stress, and securing means (8) releasably securing said stressed helix around said mandrel.

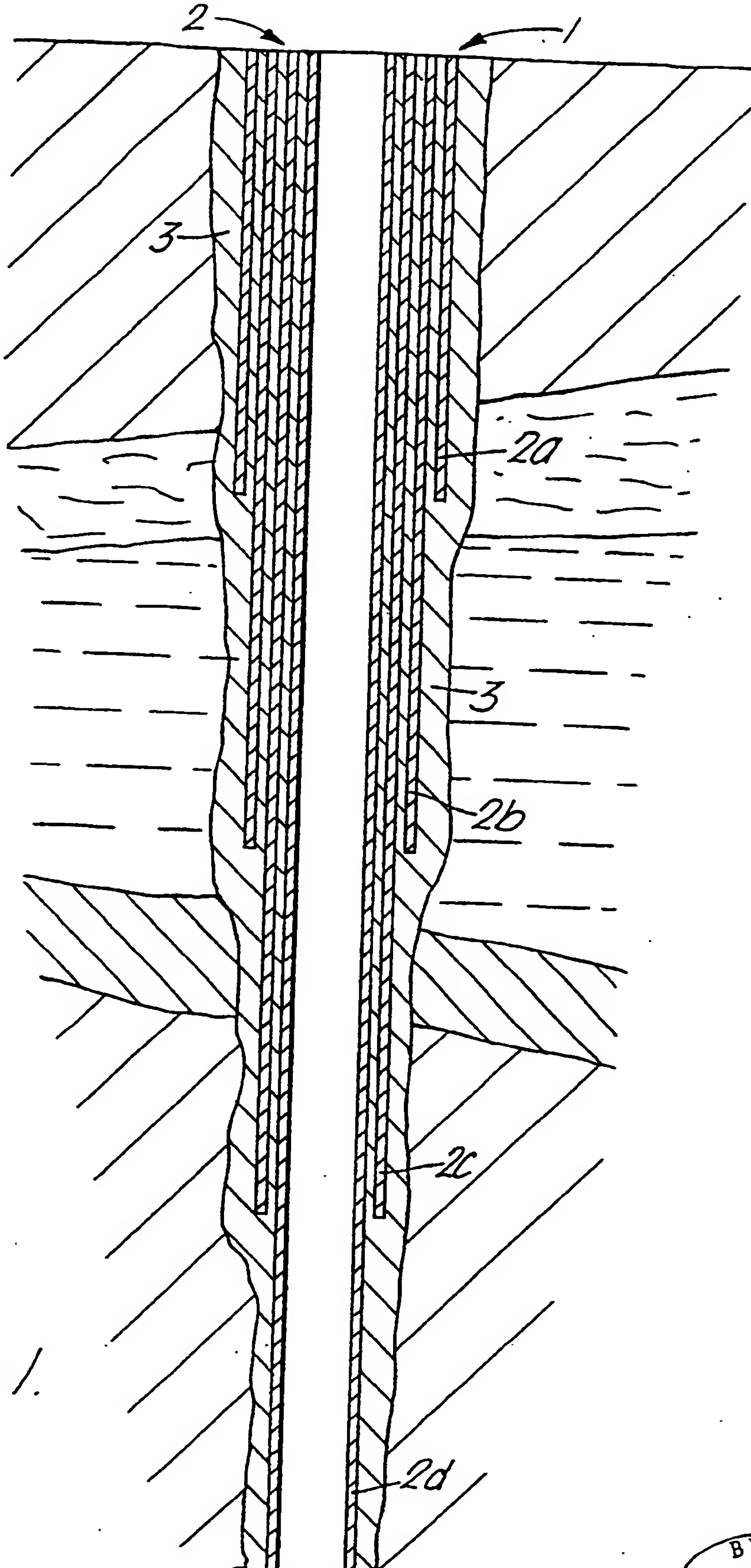

Fig. 1.

Fig. 2.

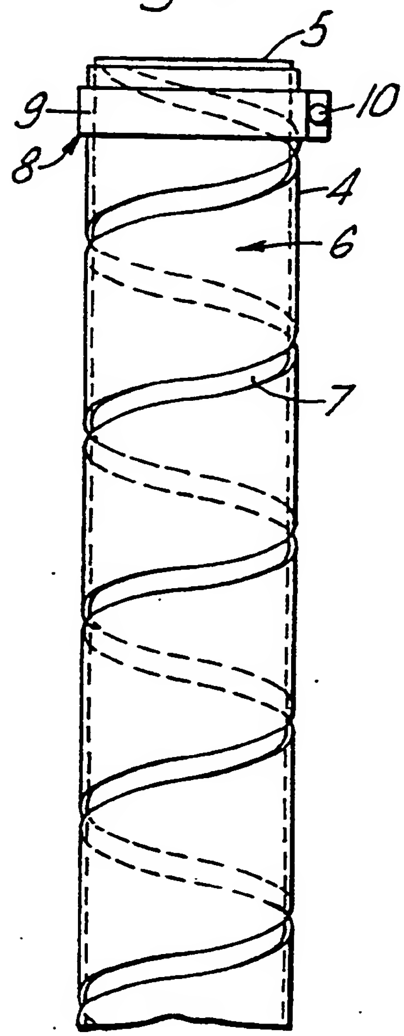

Fig. 3.

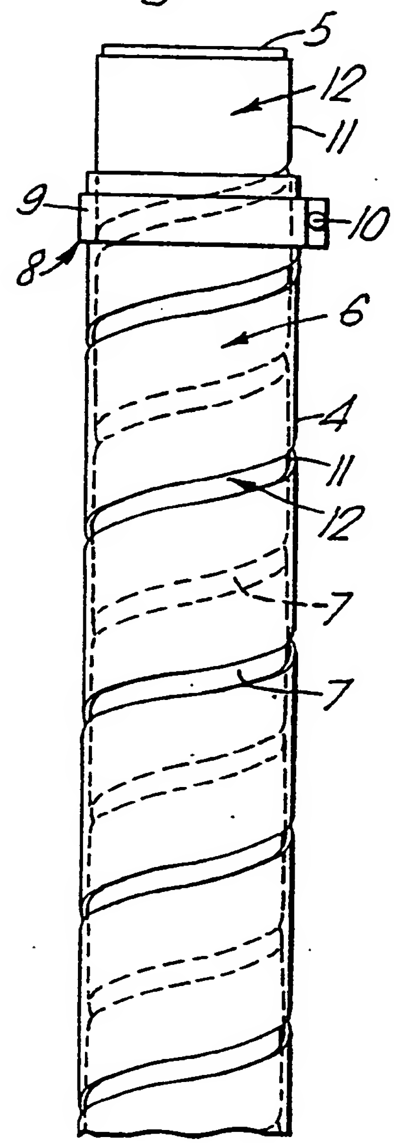

Fig. 4A.

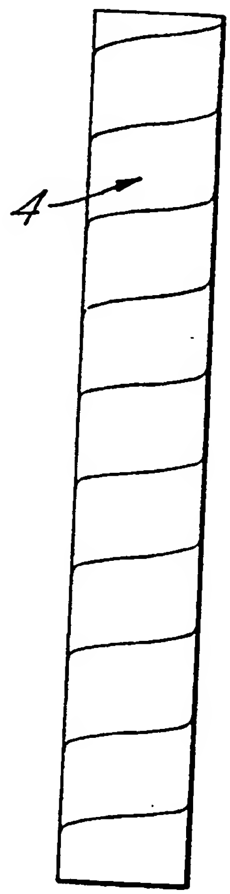

Fig. 4B.